SCIENCE

[Entered at the Post-Office of New York, N.Y., as Second-Class Matter.]

A WEEKLY NEWSPAPER OF ALL THE ARTS AND SCIENCES.

EIGHTH YEAR.
VOL. XVI. No. 398.

NEW YORK, SEPTEMBER 19, 1890.

SINGLE COPIES, TEN CENTS.
$3.50 PER YEAR, IN ADVANCE.

THE TIME-RELATIONS OF MENTAL PHENOMENA.

[Continued from p. 150.]

Association Times.

WHILE the effect of the association between stimulus and movement upon the time of the re-action has been already discussed, the process of association forms so important a factor in our mental life, that it requires a more specialized and independent investigation.

(1) *Questions with but a Single Answer.* We may view an adaptive re-action under the aspect of a "question and answer;" the stimulus being equivalent to the question, "What, with regard to certain points, is this impression?" and the answer, whether indicated by a name, or word, or movement, is given in the re-action. Our problem is to investigate the time-relations of these questions and answers, as an index of the readiness of the association between the two. The processes intervening between the appreciation of the question and the formulation of the answer may vary greatly in complexity and character. A common characteristic of the re-actions hitherto regarded consisted in the fact that the material for forming the answer is simply and directly supplied by the stimulus itself: it is in the main a verdict regarding the particular nature of sensation then present. The re-actions to which we now pass all include something more than this; and the formulation of the answer involves to a greater or less extent more complicated forms of mental activity, and depends more or less upon the past experiences, the special habits and tendencies of mind, of the individual.

While the line of division between the direct appreciation and the indirect interpretation of a sense-impression cannot be rigidly drawn, and while it is no less difficult to decide what processes are involved in this interpretation and elaboration of the sense-impression, yet we may with sufficient precision mark out as the first class of associations (α) those in which *a simple act of memory* plays the chief *rôle.* Thus, when Cattell, instead of naming a picture in his own language (which he does in 545σ), names it in German (in 694σ), the difference in time is needed for calling to mind the German name, and measures the strength of this association. Berger's acquaintance with English is less than Cattell's with German, and accordingly with him the difference between naming a picture in the vernacular and in a foreign language is greater (477σ and 649σ). The translation of a short familiar word from English to German occupies Cattell 686σ; from German to English, but 580σ; the time for long and less familiar words being much longer (we may obtain the portion of the time required for the act of translation alone by subtracting from this the time to see and name a word, 428σ). Such operations as addition and multiplication, when confined to numbers of one place, can hardly be more than acts of memory. Cattell adds such numbers in 336σ; Berger, who is a mathematician, in 221σ. The former multiplies them in 544σ; the latter, in 389σ. Vintschgau's three subjects multiply such numbers (though under different conditions) in 233σ. More complicated types of "memory re-actions" have been performed by Cattell and by Münsterberg. The former determined in separate series the time necessary, when given a city, to name the country in which it was situated (462σ); when given a month, to name the season to which it belongs (310σ), to name the following month (389σ), to name the preceding month (832σ); given an author, to name the language in which he wrote (350σ); given an eminent man, to name his sphere of activity (368σ). Münsterberg constantly varied the type of question including such as the above, the position of cities, the qualities of objects, the relations of men, and many others, finding an average time of 848σ (average of two subjects). While many of these determinations are doubtless of more individual than general value, we may stop to note a few points that are presumably typical. The re-actions here grouped under one class vary considerably in difficulty, and a few instances may be cited to indicate the range of this variation. In giving a country in which a given city is situated, the shortest time is for Paris (278σ); the longest, for Geneva (485σ). In giving the language in which an author wrote, Berger requires least time for Luther (227σ) and Goethe (265σ), most for Bacon (565σ); Cattell, least for Plato (224σ) and Shakspeare (258σ), most for Plautus (478σ). In giving the calling of an eminent man, the least time is required for poets (291σ), the longest for men of science (421σ). Münsterberg mentions as quickly answered questions (400σ to 600σ), "On what river is Cologne?" "In what season is June?" "In what continent is India?" as questions requiring a long time (1100σ –1300σ), "Who is the author of Hamlet?" "What is the color of ice?" "Who was the teacher of Plato?" An influence which we have found of great significance hitherto is equally important here; viz., the foreknowledge of the subject of what is to occur. In Cattell's experiments the general question is virtually asked once for the entire series, the special terms being given in each experiment, while in Münsterberg's results the entire question changes with each observation; and this difference in the expectancy of the subject cannot but be an important factor in the longer times found by the latter. A

somewhat different phase of this influence appears in the results of Vintschgau. In multiplying the numbers from 1×1 to 9×9, the smaller number was always announced first. Accordingly, when the first nine was announced, the subject practically anticipated the result, and had the product ready; when eight was announced, he knew that it was one of two results; when seven, one of three; and so on. Accordingly we find these to be the shortest processes (9×9, only 160σ); but there is another factor at work counteracting this effect, viz., the familiarity of certain multiplications, making the products by *one* short, and those by four and five long.

(*b*) The next type of "question and answer" will be one in which, in addition to the act of memory, a *comparison*, or a *judgment*, is involved. The result of the comparison, though not always the same for all individuals (and in this sense the question is not limited to a single answer), will probably always be the same in the same individual. The only experiment of Cattell's that seems properly to belong here is that in which the subject decided which was the greater of two eminent men (558σ). Münsterberg finds the average time for answering a miscellaneous group of such comparisons 947σ, or 99σ longer than the process without comparison: comparisons rapidly made (600σ–800σ) being, "Which has the more agreeable odor,—cloves or violets?" "Who is greater,—Virgil or Ovid?" "What is more beautiful,—woods or mountain?" and difficult questions (1200σ–1500σ) being, "Which is healthier,—swimming or dancing?" "Which do you like better,—Goethe's drama or his lyric?" "Which is more difficult,—physics or chemistry?" The comparison may be among more than two objects. Thus, in asking which is the finest of Goethe's dramas, the process of formulating the reply may include the calling to mind what the various dramas are, and a choice among them; not, of course, a considerate judgment, but the selection, under the necessity of an immediate answer, of one deciding motive. On the other hand, among the several possibilities, a certain one may, by habitual association or for other reasons, have become so prominent that virtually no comparison ensues; and the relatively slight excess in time of this type of association above the former ones (1049σ) suggests that this was often the case. To decide which is the pleasantest odor (rose), or which the most important German river (Rhine), required only between 600σ and 700σ; to decide which was the most difficult Greek author (Pindar), or your favorite French writer (Corneille), from 1400σ to 1600σ.

Münsterberg has ingeniously modified this form of experiment to show the influence of the foreknowledge or preparedness of the subject. He precedes the asking of the question by a dozen or so words of the category within which the comparison is to be made. Thus, "Apples, pears, cherries, peaches, plums, grapes, strawberries, dates, figs, raisins: which do you like better,—grapes or cherries?" Although the comparison cannot be begun until the last word is heard, still the subject has in a way anticipated the general nature of the question, as well as the scope of the comparison, and has reduced the time considerably (676σ, as compared with 947σ),—certainly a striking result.

(2) *Questions with More than a Single Answer.* In the class of re-actions to which we now pass, the question admits of several answers. The answer at one time may and need not be the same as at another time; and the determining factors in the particular character of the answer are the peculiar mental habits and tendencies of the individual. The question thus changes from a specific to a general one, the answer being any member of a more or less extended class answering to such and such a description. In some the choice may be somewhat limited. This is true of Cattell's experiments in which, given a country, we are to name a city in it (346σ); given a season, to name a month in it (435σ); given a language, to name an author writing in that language (519σ); or, given an author, to name any work of his (763σ). In all these cases we are apt to have in mind only a very few prominent instances under each head among which individual preference is exercised. In the following series the classes are more general, and accordingly the scope for individual preference much larger: given a general term to name a particular instance under that term (537σ); given a picture to name some detail of it (447σ); given the word instead of the picture, to make a similar association (439σ); given the picture or the name to mention some property of it (372σ and 337σ); given a quality to name an object to which it can be applied (351σ); given an intransitive verb to find an appropriate subject (527σ), or a transitive verb to find an appropriate object (379σ). Münsterberg has a series including a miscellaneous collection of such re-actions, and finds a time of 1036σ. Trautscholdt has investigated a similar series in which a specific instance of a general term had to be given, and finds a time of 1020σ (average of three subjects), 155σ of which must be deducted to get the pure association time.

Here, again, we may stop to consider a few generalizations which these results seem to sustain. The processes involved vary very considerably in the different experiments. Münsterberg cites as quick responses (450σ–600σ) the instancing of "a German wine (Rüdesheimer)," "of a number between ten and four (six)," "of a Greek poet (Homer);" as slow ones (1200σ–1500σ), "a beast of the desert (lion)," "a French author (Voltaire)." Trautscholdt names "mast" as "a part of a ship" in 391σ, but requires 1899σ to name "art" as "an æsthetic activity of man." These differences should appear in the average variations; that is, the average divergence of the re-action times from their mean. When the process is simple and constant, the average variation is small; when the processes are complicated and variable, the average variation is large. While in simple re-actions it is often less than 10 per cent of the re-action time, it is not infrequently as high as 30 per cent in the re-actions just considered. It may have been noticed that in certain cases the process in (2) was the reverse of that in (1). The one was a step from the whole to the part, the general to the special; while the other was from the part to the whole, the special to the general. In Cattell's case the former is the longer (433σ and 374σ). In Trautscholdt's results the conclusion comes out more clearly, the pure association time of an association of part to whole is 608σ; of whole to part, 901σ; of special to general, 754σ; of general to special, 947σ. It is thus easier to refer an individual object or quality to its class than to give an instance of a general concept. A similar result (namely, that the bond of association between two concepts is not equally strong in both directions) is derived from observing that it takes longer to recall that May precedes June than

that June follows May, longer to go back and find a subject for a verb than to go forward and find an object for it, longer when given a quality to find an object possessing that quality than to recall a quality for an object, and so on.

We may here also conveniently consider the overlapping of mental processes, which we have found takes place whenever a series of simple processes, or a complex process involving many simple ones, is performed. The general truth that the time of a complex mental operation is less than the sum of the times needed for the performance of the separate factors into which the former may be resolved, will be again illustrated Thus Münsterberg finds that it takes 103σ to name a specific instance of a class (e.g., to name a German river), 992σ to make a comparison, (e.g., Which is more important, — this river or that?) but only 1049σ to decide both questions together (e.g., Which is the most important German river?) In this case we clearly recognize that the last processes are not the sum of the preceding two, but that the category "most important German river" is already formed in the mind. The following comparisons are more illustrative. Instead of asking first, "Which is the most important German river?" (1049σ,) and then, "Which lies more westerly, — Berlin, or the most important German river?" (992σ,) we ask at once, "Which lies more westerly, — Berlin, or the most important German river?" and find the time 1855σ, or 176σ less than the sum of the two foregoing processes. Similarly, if instead of asking first, "On what river is Cologne situated?" (848σ,) and then, "Which is more westerly, — the Rhine or Berlin?" (992σ,) we ask at once, "Which is more westerly, — Berlin, or the river on which Cologne is situated?" we find a more remarkable saving of time (1314σ, or 526σ less than the sum of the two questions). This time was still further reduced to 1149σ when the question was preceded by a list of a dozen cities.

(3) *Unlimited Associations.* When we pass to the reaction of naming as rapidly as possible any word whatever, that is suggested by a given word, we are drawing entirely upon the natural associative habits of the individual, and accordingly this method has been most useful in studying psychological habits and tendencies. Our present purpose, however, is only with the time-relations of this unrestricted association. This has been the type of association first and most frequently investigated, and it is customary to speak of the pure association time as the total time minus the time needed to repeat a word. Thus Münsterberg repeats a word in 382σ, and calls out a word in association with the given word in 896σ. Trautscholdt, however, who experimented upon Wundt, Stanley Hall, and two other subjects, finds an average time of 1024σ, 727σ of which is regarded as the pure association time. Galton and others have made estimates, by rougher methods, of the rapidity with which trains of ideas pass through the mind, and the result is a rate not differing much in either direction from one association per second. It will be recognized at once that this process will be very different in different individuals and with different words. Münsterberg's shortest association was "gold–silver" (390σ); the longest, "sing–dance," "mountain–level" (1100σ–1400σ). Trautscholdt also found "gold–silver" a very quick re-action (402σ), "storm–wind" (368σ), "duty–right" (415σ). Long re-actions were "God–fearing" (1132σ), "throne–king" (1437σ), "Karl–August" (1662σ). Some interesting inferences result from the consideration of the times of different types of these unrestricted associations. Trautscholdt divides these into "word associations," or those suggested by the word rather than by the thing; "outer associations," or those relating to the sense-qualities of the object; and "inner" or logical associations. The results were 1033σ, 1028σ, 989σ, though this order may be liable to individual differences. Cattell and Berger have also compared the re-action times to concrete nouns (374σ, pure association time), to less concrete nouns (462σ), to abstract nouns (570σ), and to verbs (501σ), clearly showing that concrete terms are more readily suggestive than abstractions, and concrete objects more so than actions. Trautscholdt finds for associations to concrete nouns, 710σ; to actions, 837σ; to abstractions, 871σ.

Many of the influences to which we found simpler forms of re-action times open, are doubtless true of association times, but the great variability of the latter makes these difficult to establish. The effect of practice is noticed by Trautscholdt; and Cattell has shown that in students from thirteen to eighteen years of age a distinct shortening of the association time accompanies growth and education, while the students ranking higher in class have a somewhat shorter time than those standing low in class. Fatigue very readily enters, the accessible associations are easily exhausted, and the mind repeats itself very markedly. Changes under the action of drugs and in morbid mental states have been incidentally noticed, but still await systematic investigation.

The various processes, the times of which we have been studying, by no means exhaust the possibilities in this field. As our knowledge of mental operations becomes more perfect and more capable of experimental study, and as our power of analysis makes similar progress, the study of the time-relations of mental phenomena, already fertile in suggestions and results, will increase in interest and importance.

JOSEPH JASTROW.

MODERN EXPLOSIVES AND FLUID FUELS.[1]

SIR FREDERICK ABEL commenced with a reference to the great names in art and science which Leeds could claim as its own. He next proceeded to refer to the advances made in electrical science and its application to industrial purposes; dealing with the history of the subject since the association last met in Leeds, in 1858, and bringing it to the present day by a reference to the scheme now on foot for utilizing the power of the Falls of Niagara, electric welding, and electric smelting, the latter in connection with the production of aluminium alloys. The influence of manganese, chromium, aluminium, nickel, etc., in the manufacture of steel, was also touched upon in the address.

It was, however, when the president reached that part of his speech in which he dealt with the appliances of war, that his audience felt they had reached the most important part of his address. He traced the history of the application of gunpowder from early days, and showed how great had been the advance since the last meeting in Leeds, but more especially in quite recent times. When Sir Frederick first actively turned his attention to the subject, Doremus, in America, had proposed the employment in heavy guns, of charges consisting of large pellets of prismatic form. This powder was first used in Russia. The subject was followed up in England, Germany, and Italy. The researches of the Government Committee on Explosives, in which, as is well known, Sir Frederick and Capt. Noble took the leading part, were

[1] Abstract of an address delivered at the annual meeting of the British Association for the Advancement of Science at Leeds, Eng., by the president, Sir Frederick Abel.